THE USE OF ELASTIC SCATTERING TO CONSTRAIN THE STELLAR REACTION RATE OF $^{12}C(\alpha,\gamma)^{16}O$

Abstract

by

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The stellar reaction rate of $^{12}C(\alpha,\gamma)^{16}O$ is the most crucial unknown reaction in stellar nucleosynthetic reaction networks. At helium burning temperatures the rate depends on S(300), the astrophysical S-factor at E_{cm}=300 keV. Following α-capture, electric dipole (E1) and quadrupole (E2) transitions both contribute to the S(300), but the cross section at 300 keV is too small to be measured directly. However, $S_{E1}(300)$ and $S_{E2}(300)$ are roughly proportional to the dimensionless reduced widths θ_α^2 of two subthreshold states at E_x=7.12(1^-) and 6.92(2^+) MeV. Elastic scattering $^{12}C(\alpha,\alpha)^{12}C$ should be sensitive to the widths of these states.

Angular distributions of $^{12}C(\alpha,\alpha)^{12}C$ were measured at 32 angles ($24.0° \leq \theta_{lab} \leq 165.9°$) at 354 energies (1.95 MeV $\leq E_{cm} \leq$ 4.95 MeV) . The yields were normalized to a reference detector at 58.9° and subjected to an R-Matrix analysis. The reduced width amplitudes ($\gamma_{\lambda l}$) obtained for an interaction radius of a = 5.5 fm for the subthreshold 2^+ and 1^- states were γ_{12}=0.33±0.06 $MeV^{1/2}$ and γ_{11}=0.045±0.045 $MeV^{1/2}$, respectively. The resulting dimensionless reduced widths $\theta_{\alpha,l}^2 = 2\mu a^2\gamma_{\alpha,l}^2/3\hbar^2$ were $\theta_\alpha^2(6.92)$=0.16±0.06 and $\theta_\alpha^2(7.12)$=0.006±0.006.

The d-wave (l=2) parameters extracted from the best fit to the elastic scattering data were subsequently used in an R-Matrix fit of α-capture and ^{16}N β-delayed α-decay data. From this fit the quadrupole contribution was determined to be $S_{E2}(300)$

$= 44^{+12}_{-18}$ keV b. Including the previously established value of $S_{E1}(300)$=79±21 keV b and allowing for cascade transitions, the total S-factor is estimated to be S(300) = 137±33 keV b. The calculated reaction rate for $^{12}C(\alpha,\gamma)^{16}O$ at 300 keV then becomes 1.3±0.3 times the standard (CF88) rate.